

A REVIEW OF CARBON CAPTURE AND STORAGE IN CALIFORNIA

**DRAFT Background Report to Recommendations**  
**by the California Carbon Capture and Storage Review Panel**

A Report to the California Energy Commission, the California Public Utility Commission,  
and the California Air Resources Board

12/31/2010

## Contents

1. Overview of the Carbon Capture and Storage Panel Review Process .....	1
1.1. Introduction .....	1
1.2. The Carbon Capture and Storage Review Panel.....	1
1.3. Need for a Clear State Policy and Regulatory Framework.....	2
2. California Policy Context for CCS.....	2
2.1. Current State Policy.....	2
2.2. Perspectives on the Role of CCS in California.....	5
2.3. Deployment Considerations for Geologic CCS in California .....	7
2.4. Health and Safety Issues and Related History.....	8
2.5. California CCS Policy in Context with Federal Developments .....	9
2.6. Policy Developments in Other States .....	12
3. Issues Requiring Attention and Resolution to Enable Safe and Effective CCS Demonstrations and Commercial Deployment in California.....	12
3.1. The Regulatory Framework for CCS Projects.....	12
3.2. Regulation and Permitting of CO <sub>2</sub> Pipelines.....	14
3.3. Regulation of CO <sub>2</sub> Injection Under Current California Law .....	16
3.4. Ownership of Pore Space for CO <sub>2</sub> Storage .....	16
3.5. Requirements for Monitoring, Reporting, and Verification .....	17
3.6. Long-Term Stewardship of Storage Sites.....	18
3.7. Commercial Considerations/Incentives/Policy Drivers.....	19
3.8. Role of Public Outreach, Education, and Acceptance.....	20
3.9. Environmental Justice .....	21
4. Appendices (in development).....	23
Appendix A: Charter of the California Carbon Capture and Storage Review Panel .....	23
Appendix B: Members of the California Carbon Capture and Storage Review Panel .....	24
Appendix C: California Carbon Capture and Storage Review Panel Meeting List of Presenters .....	24
Appendix D: Carbon Capture and Storage Technical Advisory Team.....	24
Appendix E: Uses of Carbon Dioxide.....	24
Appendix F: Geologic Suitability .....	24
Appendix G: Review of Saline Formation Storage Potential in California .....	24
Appendix H: Federal Overview .....	24
Appendix I: State-based Overview .....	24
Appendix J: Carbon Dioxide Pipelines.....	24
Appendix K: Approaches to Pore Space Rights .....	24
Appendix L: Public Outreach Considerations for CCS in California .....	24
Appendix M: Environmental Justice.....	24
Appendix N: AB 32 Regulations and CCS.....	24

Appendix O: Options for Permitting Carbon Capture and Sequestration Projects in California.....	24
Appendix P: Enhanced Oil Recovery as Carbon Dioxide Sequestration.....	24
Appendix Q: Long-Term Stewardship and Long-Term Liability in the Sequestration of CO <sub>2</sub> .....	24
Appendix R: Monitoring, Verification, and Reporting Overview .....	24
Appendix S: Overview of the Risks of Geologic CO <sub>2</sub> Storage .....	24
Appendix T: Establishing Eminent Domain Authority for Carbon Storage in California.....	24

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## **Abbreviations and Acronyms**

ARB – California Air Resources Board  
BACT – best available control technology  
CAA – Clean Air Act  
CEQA – California Environmental Quality Act  
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act  
CPUC – California Public Utilities Commission  
DOE – U.S. Department of Energy  
DOGGR – Division of Oil, Gas and Geothermal Resources  
DOT – Department of Transportation  
EJ – Environmental Justice  
Energy Commission – California Energy Commission  
EOR – enhanced oil recovery  
EPA – U.S. Environmental Protection Agency  
EPS – Emissions Performance Standard  
FERC – Federal Energy Regulatory Commission  
GHG – greenhouse gas  
LGP – loan guarantee program  
MRR – mandatory reporting rule  
MRV – monitoring, reporting, and verification  
NGA – Natural Gas Act  
PHMSA – Pipeline and Hazardous Materials Safety Administration  
PSD – Prevention of Significant Deterioration [program]  
SIP – State Implementation Plan  
SDWA – Safe Water Drinking Act  
UIC – underground injection control  
USDW – underground sources of drinking water  
WCI – Western Climate Initiative  
WESTCARB – The West Coast Regional Carbon Sequestration Partnership

## **1. Overview of the Carbon Capture and Storage Panel Review Process**

### **1.1. Introduction**

California policy commits the state to reducing greenhouse gas (GHG) emissions. To meet this commitment, considerable efforts are focused on improving end-use energy efficiency and increasing the amount of electricity produced from renewable energy resources. These measures are expected to suffice to meet the 2020 goal of reducing the state's GHG emissions to 1990 levels. However, to meet the more stringent 2050 goal of 80 percent below 1990 levels, it will be necessary for the state to deploy additional technologies such as carbon capture and storage (CCS).

CCS refers to climate change mitigation technologies that capture carbon dioxide (CO<sub>2</sub>) and store it long-term to reduce the accumulation of CO<sub>2</sub> in the atmosphere. Geologic CCS captures CO<sub>2</sub> from industrial sources and sequesters the gas in deep-lying subsurface geologic formations. Terrestrial CCS refers to methods that enhance the naturally occurring storage of carbon in ecosystems such as forests, rangelands, agricultural lands, and wetlands.

The largest contributors to California's GHG emissions inventory, after transportation, are large industrial and electric power generating facilities. California's electricity sector is primarily supplied by in-state natural gas combined cycle plants, while out-of-state coal-fired plants account for 20 percent of electrical supply. Other large California point sources include cement plants and oil refineries. The application of CCS to new and existing facilities, both in- and out-of-state, could significantly lower their CO<sub>2</sub> emissions contributions to California's GHG inventory.

To justify capital investments in CCS technology, industry needs to know with certainty how CCS will be regulated, how carbon will be valued as a commodity, and how the emissions reductions from geologic storage will be treated under a state-administered cap-and-trade program. Although recent actions at the federal level have clarified significant regulatory issues for geologic storage of CO<sub>2</sub>, gaps remain in California law and/or regulation, which necessitate the state taking its own steps to develop appropriate regulations—and, if necessary, new laws—to regulate CCS.

CCS is recognized by state, national, and international policymakers as necessary for meeting long-term energy and climate change mitigation goals. Because California is a leader in addressing GHG emissions, it is imperative for the state to demonstrate additional initiative in supporting a range of technologies that cover all major types of emissions sources. Integrating CCS into the state's policy mechanisms will facilitate commercial adoption of this critical technology by the industrial and electricity sectors and better position the state to meet its target GHG reduction levels.

### **1.2. The Carbon Capture and Storage Review Panel**

Recognizing the importance of CCS for California's industrial and electricity sectors, the California Public Utilities Commission (CPUC), California Energy Commission (Energy Commission), and the Air Resources Board (ARB) created a CCS Review Panel in February 2010. The Panel, composed of experts from industry, trade groups, academia, and environmental organizations, was asked to:

- Identify, discuss, and frame specific policies addressing the role of carbon capture and storage in meeting the state's energy needs and greenhouse gas reduction goals.
- Review CCS policy frameworks used elsewhere, and identify gaps, alternatives, and applicability in California.
- Develop specific committee recommendations on CCS.

The Panel held five public meetings on April 22, June 2, August 18, October 21, and December 15, 2010, to arrive at its recommendations. These meetings were designed to solicit input from technical experts and key stakeholders and to allow Panel members to deliberate among themselves in an open, public setting. The Panel was asked to submit its written recommendations to the three principal agencies by the end of 2010.

Appendix A contains the Charter for the Panel. Appendix B contains a list of the Panel members and their qualifications. Appendix C has links to public testimony, presentation materials, and written comments. A Technical Advisory Team (TAT) of state agency representatives and expert consultants was also formed to assist the Panel in its deliberations. A listing of TAT members is in Appendix D. White papers produced by TAT members, as well as other relevant materials, are included in subsequent Appendices.

### **1.3. Need for a Clear State Policy and Regulatory Framework**

For CCS technologies to become part of California's climate change mitigation effort, a clear, transparent, flexible, and adaptable statutory or regulatory framework is needed. There are, at present, no commercial-scale CCS projects in California. For projects in the planning stages, unresolved economic, regulatory, and statutory issues present significant impediments to developers. Some issues, such as injection well classification and emissions accounting, are being addressed by the U.S. Environmental Protection Agency (EPA) at the federal level.<sup>1</sup> However, other critical gaps or areas of ambiguity remain, including long-term liability for stored CO<sub>2</sub> and pore-space ownership. The latter is generally conceded to fall under the purview of the states, which have historically adjudicated property rights.

The charter of the CCS Review Panel was developed to determine ways to address some of the most significant regulatory, institutional, and policy challenges facing CCS technology adoption in California. The Panel's recommendations are designed to (1) support consideration of new state legislation that addresses statutory gaps, (2) identify state policy instruments or incentives to facilitate CCS adoption, and (3) assist in establishing regulatory authority, including delineating the roles and responsibilities of key state permitting agencies.

## **2. California Policy Context for CCS**

### **2.1. Current State Policy**

On June 1, 2005, Governor Schwarzenegger signed Executive Order S-3-05, which established target reduction levels for GHG emissions in California: 2000 levels by 2010; 1990 levels by 2020; and 80 percent below 1990 levels by 2050. With the passage of Assembly Bill 32, the Global Warming Solutions Act of 2006, (Núñez, Chapter 488, Statutes of 2006), California adopted the second target of reducing GHG emissions to 1990 levels by 2020. AB 32 directed ARB to begin developing discrete early actions to reduce greenhouse gases while preparing a scoping plan to identify how best to reach the 2020 limit.

Senate Bill 1368, (Perata, Chapter 598, Statutes of 2006), followed with a mandate for new or renewed long-term contracts to purchase electricity from baseload facilities to meet the GHG emission performance standard (EPS) of 1100 lbs CO<sub>2</sub>/MWh established by CPUC and the Energy Commission, in consultation with ARB.

Assembly Bill 1925, (Blakeslee, Chapter 471, Statutes of 2006), passed unanimously by the California Legislature, aimed to provide policymakers with an assessment of the present level of development of geologic CCS and its potential application to meeting California's emission reduction goals. The bill directed the Energy Commission, in coordination with the Department of Conservation, to prepare a

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<sup>1</sup> <http://www.epa.gov/climatechange/emissions/>

report for the Legislature. Published in 2008, the “AB 1925 report”<sup>2</sup> elucidated the potential for CCS technologies to contribute significantly to the state’s GHG emissions reductions. What remains unclear is how CCS, whether by geologic, terrestrial, or beneficial use applications, fits into California’s overall strategy or policies to reduce its GHG emissions. Studies of strategies to meet either the 2020 goals of AB 32 or the longer-term 2050 goals of Executive Order S-3-05 have generally not included CCS options.

### **Emissions Performance Standards**

The current regulations implementing SB 1368 allow for the use of CCS to meet the EPS, but the mechanisms for determining compliance are unclear. The Energy Commission regulation states that for covered procurements that employ geologic CO<sub>2</sub> storage, the successfully sequestered CO<sub>2</sub> emissions shall not be included in the annual average CO<sub>2</sub> emissions. The EPS for such power plants shall be determined based on projections of net emissions over the life of the power plant. CO<sub>2</sub> emissions shall be considered successfully sequestered if the sequestration project meets the following requirements:

- Includes the capture, transportation, and geologic formation injection of CO<sub>2</sub> emissions;
- Complies with all applicable laws and regulations; and
- Has an economically and technically feasible plan that will result in the permanent sequestration of CO<sub>2</sub> once the sequestration project is operational

These requirements differ from AB 32 requirements in a few key ways.<sup>3</sup> First, the EPS is based on emissions over the lifetime of the plant whereas AB 32 is based on annual emissions, and the low carbon fuel standard (LCFS) considers life-cycle emissions (including indirect emissions). Second, the EPS requires an economically and technically feasible plan for permanent storage, while AB 32 accounting would need a quantification methodology for any emissions and verification of permanent storage. The definition of permanent storage is not included and may have different criteria than those under the AB 32 regulations (which have yet to be defined).

### **Low Carbon Fuel Standard**

Executive Order S-01-07 directed ARB to create a LCFS to help meet the 2020 goal outlined in AB 32. The order calls for a reduction of at least 10 percent in the carbon intensity of California’s transportation fuels by 2020. The LCFS is separate from Mandatory Reporting and the Cap-and-Trade Program and has its own reporting tools and offset requirements. The LCFS framework is based on the premise that each fuel has a “life-cycle” GHG emission value that is then compared to a standard. The life-cycle analysis includes the direct emissions associated with producing, transporting, and using the fuels, as well as additional emissions, direct and indirect, derived from effects of using that fuel—for example, emissions that result from changes in land use for crop-based fuels.

The standards are expressed as the carbon intensity of gasoline and diesel fuel and their alternatives in terms of grams of CO<sub>2</sub> equivalent per megajoule (gCO<sub>2</sub>E/MJ). Providers of transportation fuels must demonstrate that the mix of fuels they supply meet the LCFS intensity standards for each annual compliance period by reporting all fuels and tracking the fuels’ carbon intensity through a system of credits and deficits. Credits are generated from fuels with lower carbon intensity than the standard. Deficits result from the use of fuels with higher carbon intensity than the standard. A regulated party meets its compliance obligation by ensuring that the amount of credits it earns (or acquires) is equal to or

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<sup>2</sup> Burton, Elizabeth A., Richard Myhre, Larry Myer, and Kelly Birkinshaw, *Geologic Carbon Sequestration Strategies for California, Report to the Legislature*. California Energy Commission, Systems Office. CEC-500-2007-100-CMF.

<sup>3</sup> See *AB 32 Regulations and CCS* in Appendix N.

greater than the deficits it has incurred. Credits may be banked and traded within the LCFS market to meet obligations.

CCS is specified as an option for producers of high carbon intensity crude oil to reduce emissions for production and transport of crude oil to less than 15 gCO<sub>2</sub>e/MJ. CCS could also be considered when used for the production of alternative fuels such as hydrogen and compressed natural gas for electricity generation. For CCS to be incorporated into the LCFS, a quantification methodology would be necessary.

### **The Cap-and-Trade Program and the Mandatory Reporting Regulation**

A 2007 report released by the Governor's Market Advisory Committee to the ARB contains the first published recommendations on the design of a cap-and-trade system to reduce GHG emissions in California.<sup>4</sup> This report outlines the various opportunities and challenges of different design elements in an emissions trading program. A primary purpose of a cap-and-trade program is to bring about low-cost emissions reductions within the sectors covered by the program. A cap limits emissions and creates a market for trading GHG emissions allowances, where every ton of emissions has a price. The report outlines four different options for defining the scope of a California GHG cap-and-trade program. All of the options create price signals for carbon reducing technologies, including CCS, the strength of which would depend on the relative costs of allowances compared to the costs of implementing the various technologies.

In November 2009, ARB released preliminary draft regulations for a cap-and-trade program. The program relies on standardized methods established by the Mandatory Reporting Regulation (MRR) of 2007 (effective January 2009) to provide the source emissions data to support trading. Consistent with AB 32, ARB must adopt the cap-and-trade regulation by January 1, 2011, and the program itself must begin in 2012.

California is also working closely with six other western states and four Canadian provinces through the Western Climate Initiative (WCI) to design a regional cap-and-trade program that can deliver GHG emission reductions within the region at costs lower than could be realized through a California-only program. To that end, the ARB rule development schedule is being coordinated with the WCI timeline for development of a regional cap-and-trade program.

In California, the MRR adopted by ARB provides standardized methods for entities to measure, monitor, report, and verify emissions. The MRR methods were used by California's largest industrial GHG emitters to report their 2008 emissions and by electricity retail providers and marketers to report electricity transaction information for that year. The cap-and-trade program will become effective gradually, starting in 2012, with the largest industrial point sources, and will grow to include smaller industrial point sources, transportation fuels, and commercial and residential propane and natural gas combustion in 2015. ARB will use MRR data to determine which entities have a compliance obligation and how many compliance instruments each entity must surrender. An entity will have to offer allowances or offset credits for each metric ton it reports emitting.

Conceptually, CCS may play a role in the cap-and-trade program in one of two ways: (1) CCS could be applied to emissions of a capped source and reported via the MRR; (2) a non-capped source could apply CCS to its emissions, producing an offset credit that could then be obtained by a capped entity. In both cases, however, the lack of a quantification protocol, either in the MRR or through an offset protocol, means that CCS is not incorporated into the cap-and-trade program at this time. Nor presumably, for the same reasons, can CCS qualify for early reduction allowances under the WCI plan.<sup>5</sup>

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<sup>4</sup> <http://www.energy.ca.gov/2007publications/ARB-1000-2007-007/ARB-1000-2007-007.PDF>

<sup>5</sup> <http://westernclimateinitiative.org/the-wci-cap-and-trade-program/program-design>



## **GHG Accounting for CCS Under Other Regimes**

EPA, the European Union, the Intergovernmental Panel on Climate Change, non-profits, and industry organizations are developing or have developed national and international accounting guidelines or systems for CCS to ensure that CO<sub>2</sub> can be quantified and verified as permanently stored. Any of these systems could be adapted to comply with ARB's programs, which also require an accurate accounting of the CO<sub>2</sub> during capture, transport, and storage. It should be noted, however, that monitoring requirements for emissions accounting purposes may differ from those for protecting human health and safety, drinking water, or other resources.

## **2.2. Perspectives on the Role of CCS in California**

### **Oil and Gas Industry**

Enhanced oil recovery (EOR) using CO<sub>2</sub> is commonly practiced in Texas and New Mexico but not in California, due to a lack of local, large-volume CO<sub>2</sub> supplies. The potential for commercial-scale anthropogenic supplies of CO<sub>2</sub> from capture processes applied to in-state facilities is creating increased interest in CO<sub>2</sub>-EOR by California oil and gas producers.

The oil and gas industry has nearly 40 years of experience transporting and injecting CO<sub>2</sub> for EOR. In the United States alone, the industry operates more than 13,000 CO<sub>2</sub>-EOR wells, over 3,500 miles of high pressure CO<sub>2</sub> pipelines, and has injected approximately 600 million tons of CO<sub>2</sub> for EOR, all while maintaining an excellent health, environment, and safety record.<sup>6</sup> Currently, over 2 billion cubic feet of CO<sub>2</sub> is injected underground each day in EOR operations in West Texas, producing an additional ~250,000 barrels of oil a day.<sup>7</sup>

When CO<sub>2</sub> is used during EOR, sequestration occurs as part of the process. For this reason, public policy that encourages the use of anthropogenic CO<sub>2</sub> for EOR will also be supporting GHG emissions reductions, along with increased domestic energy production.

The technology, operating procedures, and regulatory requirements that have been developed for CO<sub>2</sub>-EOR are extensive, mature, and generally appropriate for CCS. The underground injection of CO<sub>2</sub> for enhanced recovery of hydrocarbons is fully and adequately regulated by EPA under the Clean Water Act's Underground Injection Control (UIC) Program<sup>8</sup> and other environmental regulatory programs (i.e., air, water, and solid waste programs).

Given the established nature, safety record, and economic value of CO<sub>2</sub>-EOR operations, an approach that encourages CO<sub>2</sub>-EOR for GHG emissions reductions will want to allow such projects to function as much as possible within the existing regulatory framework for EOR operations, while still ensuring that the monitoring, verification, reporting, and closure standards of applicable federal or state GHG emissions programs are met.

Further discussion of CO<sub>2</sub>-EOR is found in Appendix P.

### **Electric Power Generation**

In order for the state to achieve its aggressive GHG reduction goals, the electricity sector needs to build low-carbon generation. There are three possible approaches to decarbonizing the electricity sector, which

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<sup>6</sup> Parker, M., J. Meyer, and S. Meadows, *Carbon Dioxide Enhanced Oil Recovery Injection Operations Technologies* (Poster Presentation), 9th International Conference on Greenhouse Gas Control Technologies, 16–20 November 2008, Washington D.C.

<sup>7</sup> Ibid.

<sup>8</sup> <http://water.epa.gov/type/groundwater/uic/index.cfm>

can be used in combination:

- Renewable energy
  - Renewable energy development is required under California's Renewable Portfolio Standard, and will likely play an expanding role in the state's energy portfolio. However, permitting for new sites and transmission lines is meeting opposition in some instances, and the intermittent output profile of wind and solar, without significant investments in energy storage, raises questions of grid reliability.
- Nuclear energy
  - New nuclear power is banned in California until there is a permanent federally managed repository for nuclear waste or reprocessing of spent nuclear fuel has been demonstrated and approved in the United States.. Finding safe and socially acceptable ways to deal with nuclear waste remains a challenge for nuclear power.
- CCS
  - A Low Carbon Portfolio Standard is needed to reward utilities for purchasing electricity with CCS.

At this point, it is extremely difficult to accurately determine the costs of CCS to the electric utilities and their ratepayers. However, early adopters' financial numbers show that the addition of CCS adds considerable expense to the operation of those facilities. For the utilities, the costs of CCS will be passed on to ratepayers through Power Purchase Agreements. This issue will need to be addressed by the state government and the CPUC, working with consumer advocates and the utility sector.

In recognition of the advantages to the state that come from being in a leadership position in deploying CCS technologies and of the public-interest benefits of early mover projects, which will be shared by all Californians, the costs could also be spread to all Californians. For the electric sector, this would ease concerns that CCS could pose undue financial burdens to any single utility and its ratepayers.

### **Other Industries**

To date, technologies making beneficial use of CO<sub>2</sub>, including EOR, have had a negligible impact on overall anthropogenic CO<sub>2</sub> emissions.<sup>9,10</sup> Eventually, new technologies that facilitate the use of CO<sub>2</sub> may someday increase the market demand for CO<sub>2</sub> captured from power plant and industrial sources, thus improving the economic viability of CO<sub>2</sub> capture, while reducing GHG emissions and providing useful products to the public.

Possible CO<sub>2</sub> use technologies include those that combine geological storage of CO<sub>2</sub> and energy production, in a manner somewhat analogous to EOR, such as enhanced gas recovery or enhanced geothermal systems, where CO<sub>2</sub> replaces water as a heat exchange fluid. In this general category of CO<sub>2</sub>-use technology, CCS is joined to the enhanced recovery of a geological resource, such as oil, natural gas, geothermal heat, minerals, or water.

There are other types of CO<sub>2</sub>-use technologies, where the CO<sub>2</sub> is either stored non-geologically, or is used in such a way as to reduce net GHG emissions. The former include the synthesis from a CO<sub>2</sub> feedstock of solid materials such as plastics, or carbonates that can be used in cement or construction materials, which result in the carbon being trapped within the solid material. The latter include CO<sub>2</sub>-to-fuels technologies.

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<sup>9</sup> Intergovernmental Panel on Climate Change, Carbon Dioxide Capture and Storage: Chapter 7 Mineral carbonation and industrial uses of CO<sub>2</sub>. Cambridge University Press, UK. 2005.

<sup>10</sup> Tiina Koljonen, Hanne Siikavirta, Ron Zevenhoven, CO<sub>2</sub> Capture, Storage and Utilization in Finland, Project Report, VTT Processes, Systems and Models, Aug. 29, 2002, [www.vtt.fi/inf/julkaisut/muut/2002/co2capt.pdf](http://www.vtt.fi/inf/julkaisut/muut/2002/co2capt.pdf)

A more detailed discussion on the uses of CO<sub>2</sub> is provided in Appendix E.

### **2.3. Deployment Considerations for Geologic CCS in California**

Widespread deployment of geologic CCS in the state will require integrated assessments that include engineering analysis of sources, analysis of pipeline, rail, or other transportation alternatives, and geologic characterization of the subsurface at sequestration sites. One such preliminary assessment, currently being undertaken by the West Coast Regional Carbon Sequestration Partnership (WESTCARB), focuses on existing and newly permitted natural gas combined cycle power plants, which predominate in California's electricity generation mix. Any future energy infrastructure planning or assessments done by the state that include fossil fuel sources could also include provision for such integrated CCS assessments.

#### **Sources**

For 2008, the state's GHG reporting data<sup>11</sup> show that the largest in-state emissions come from refineries, natural gas electricity production, and cement plants. For the electric power sector, it is important to note that emissions counted in the state's inventory include in-state and out-of-state GHG emissions. Plans for CO<sub>2</sub> emissions reduction in the transportation sector typically focus on using lower net carbon fuels, such as electric-powered vehicles, which would shift emissions from the transport to the power sector.

Effective initial deployment of CCS to achieve the greatest impact on the state's GHG emissions might best be focused on the largest in-state point sources, and also on out-of-state sources in the context of regional climate change initiatives and in consideration of the western regional energy infrastructure. By 2050, assuming moderate economic growth, achieving the 2050 target level of about 90 MMT/year would require reducing emissions by 10 MMT/year each year starting in 2010, or 14 MMT/year starting in 2015.<sup>12</sup> While it seems evident that CCS technology must play an important role in achieving these reductions, deployment may not be rapid enough (even with policies that enable an economically favorable case for CCS adoption) if it is not accompanied by sufficient understanding of the sequestration resource potential or transport and other infrastructure development.

#### **Transport of CO<sub>2</sub><sup>13</sup>**

Where large point sources do not overlie suitable sequestration sites, CO<sub>2</sub> will be transported via pipelines or on trucks, trains, ships, or barges. In today's commercial markets, CO<sub>2</sub> is routinely transported in tanker trucks as liquid CO<sub>2</sub>; however, for the large quantities of CO<sub>2</sub> involved in CCS, tanker transport is impractical and uneconomic. Rail has been considered viable in some cases, but pipelines are the most likely mode of CO<sub>2</sub> transport for commercial-scale sequestration operations.

The technical, economic, and permitting issues associated with CO<sub>2</sub> compression and pipeline transport are well understood because of the large-scale use of CO<sub>2</sub> for over 20 years in EOR operations in many other states. To assure single phase flow and optimize volumetric flow, the CO<sub>2</sub> is typically compressed at the source to a supercritical state—150 bar (2200 pounds per square inch) or more, and non-condensable gases (nitrogen and oxygen, for example) are removed. Booster compressors may be necessary along lengthy pipelines. To avoid corrosion and hydrate formation, water levels are typically kept below 50 parts per million.

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<sup>11</sup> California Air Resources Board, Mandatory GHG Reporting Data, Emissions Reported for Calendar Year 2008 <http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep.htm>

<sup>12</sup> Schiller, S. "Implications of Defining and Achieving California's 80% Greenhouse Gas Reduction Goal," California Institute for Energy and Environment. Fourth Annual California Climate Change Conference. Sacramento, CA 9-13-2007.

<sup>13</sup> Adapted from: Burton, op. cit.

More information on CO<sub>2</sub> pipelines can be found in Appendix J.

### **Geologic Suitability**

In California, suitable geologic formations for CO<sub>2</sub> storage include depleted or near-depleted oil and gas reservoirs, as well as saline formations (rocks containing non-potable salty water). These targets are common in deep sedimentary basins, where sand and mud have accumulated to great thickness over many millions of years and lithified (compacted under pressure into rock). These types of layered rocks are potentially good storage sites because they have the capacity to hold (trap) large amounts of CO<sub>2</sub> in the pore spaces of permeable layers such as sandstone, while overlying impermeable mud-rock layers form good seals that prevent the gas from escaping upward. Optimal sequestration takes place at depths below 2,500 feet (800 meters) where pressures and temperatures keep CO<sub>2</sub> in a liquid-like, supercritical phase, which makes it less buoyant.

As part of the WESTCARB project, the California Geological Survey (CGS) developed a preliminary screening method to identify sedimentary basins in California with the greatest geologic potential for CO<sub>2</sub> sequestration.<sup>14</sup> The CGS initially identified and cataloged 104 sedimentary basins that underlie approximately 33 percent of the area of the state. For basins that passed the initial screening, available data were used to make preliminary determinations of potential storage resource capacity. A total of 27 basins met the screening criteria. Using the methodology developed to support National Energy Technology Laboratory's Carbon Sequestration Atlas of the United States and Canada, the CO<sub>2</sub> storage "resource" for the 10 onshore basins was calculated to be between 75 and 300 gigatonnes of carbon dioxide (GT CO<sub>2</sub>). For oilfields, preliminary estimates are on the order of 1.3 to 3.4 GT CO<sub>2</sub>, and for natural gas fields, from 3.0 to 5.2 GT CO<sub>2</sub>. The preliminary estimates indicate that the resource for geologic storage of CO<sub>2</sub> is ample. For comparison, the CO<sub>2</sub> emissions from power and industrial sources in California are currently about 0.08 GT per year. Final selection of any sequestration site in California will require detailed site-specific data and detailed analysis of the subsurface.

Appendices F and G contain more information on geologic storage potential in California.

### **2.4. Health and Safety Issues and Related History**

The risks to human health and the environment associated with CO<sub>2</sub> capture, transport, and geologic storage need to be taken into consideration in the development of CCS policy for California. The possible adverse effects from a concentrated CO<sub>2</sub> leak from a storage site, a pipeline or other form of transport, or from the chemicals used during capture at industrial facilities must be guarded against by enacting policies to ensure proper site selection and characterization, monitoring and safety measures, and mitigation planning.

Although the idea of intentionally storing large quantities of CO<sub>2</sub> in underground geologic formations for extended periods is relatively new, established industrial operations—including petroleum exploration and production, EOR using CO<sub>2</sub>, underground natural gas storage, and disposal of acid gas and hazardous wastes—provide many decades of relevant knowledge and experience for determining the risks of geologic storage. This experience base also provides the methods, tools, and approaches to manage these risks through careful site selection, characterization, injection, and monitoring.

CO<sub>2</sub> is non-toxic and nonflammable. Humans exhale CO<sub>2</sub> and plants uptake CO<sub>2</sub> for photosynthesis. However, there are rare examples of naturally occurring CO<sub>2</sub> in volcanic regions posing risks of asphyxiation in humans and animals. High concentrations in the soil will also stress vegetation and can

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<sup>14</sup> Downey, Cameron and John Clinkenbeard, 2006, *An Overview of Geologic Carbon Sequestration Potential in California*. California Energy Commission, PIER Energy-Related Environmental Research, CEC-500-2006-088.

eventually kill it. Careful consideration must therefore be given to the selection of pipeline routing, storage sites, development of operational procedures to guard against leakage, and monitoring procedures to check for leaks during operation and after injection stops.

An abrupt failure of a pipeline could lead to a high velocity release of CO<sub>2</sub>, although it will not explode because CO<sub>2</sub> is nonflammable. The possibility of such an event needs to be taken into consideration in the design, construction, operating, and monitoring procedures for CO<sub>2</sub> pipelines. Loss of control of wells could also lead to high velocity releases of CO<sub>2</sub> (well blowouts). Such a release would not produce a fire or a toxic spill, but the risks of well blowouts must still be taken into consideration in the design, construction, and operation of CO<sub>2</sub> wells.

Induced seismicity is another risk consideration during CO<sub>2</sub> injection operations. It is well recognized that injecting fluids into the subsurface can result in seismic events, although the vast majority of these are not recognized as earthquakes because they do not release enough energy to be felt at the surface. In fact, there is an entire technology associated with the use of these small events, called microseismic events, as a tool for monitoring the movement of fluids in the subsurface. Although rare, there have been instances in which non-CCS injection operations—including some engineered geothermal operations—have resulted in ground motion that was felt by near-by communities. Seismic risks therefore need to be taken into consideration during site selection and in the design, operation, and monitoring of CO<sub>2</sub> storage projects. The identification and proximity of active faults will need to be considered during site selection, and specialized seismic monitoring may be warranted as part of the overall monitoring, verification, and reporting (MRV) plan.

Appendix S contains more information on the risks of geologic CO<sub>2</sub> storage.

## **2.5. California CCS Policy in Context with Federal Developments**

There has been considerable activity on the federal level that impacts CCS from a regulatory and institutional perspective. In addition to the section below, additional information on federal activities can be found in Appendix F.

### **Source Emissions**

Stationary source emissions of GHGs are now subject to regulation under the federal Clean Air Act (CAA),<sup>15</sup> pursuant to the decision of the United States Supreme Court in *Massachusetts v. EPA*, 549 U.S. 497 (2007), which held that GHGs met the CAA's definition of "air pollutant." Pursuant to the *Massachusetts v. EPA* decision, the EPA issued its so-called "Endangerment Finding" on December 15, 2009.<sup>16</sup> In the Endangerment Finding, EPA concluded that six GHGs—carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride—may reasonably be anticipated to endanger public health and welfare. On the same day, EPA issued what is known as its "Cause or Contribute Finding," in which it defined the applicable "air pollutant" as the same six GHGs, in aggregate, and found that this new "air pollutant," when emitted from new motor vehicles and new motor vehicle engines, contribute to GHG air pollution that endangers public health and welfare.

On April 2, 2010, EPA published a notice that is known as the "Johnson Memo Reconsideration."<sup>17</sup> In that notice, EPA interpreted the CAA term "subject to regulation," which is one of the regulatory triggers for permitting under the CAA's Prevention of Significant Deterioration (PSD) program. The Johnson Memo Reconsideration concluded that EPA's imposition of GHG tailpipe emission standards for certain

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<sup>15</sup> 42 U.S.C. § 7401 et seq.

<sup>16</sup> 74 Fed. Reg. 66496 (Dec. 15, 2009).

<sup>17</sup> 75 Fed. Reg. 17004 (April 2, 2010).

mobile sources (which were subsequently published on May 7, 2010),<sup>18</sup> would trigger PSD applicability for GHG-emitting stationary sources on or after January 2, 2011, which is the date when the GHG tailpipe emissions standards took effect. On June 3, 2010, EPA published what is commonly referred to as the “Tailoring Rule,”<sup>19</sup> which limits the applicability of PSD permitting for GHGs to only the highest-emitting GHG sources; in the absence of the Tailoring Rule, the PSD program’s existing 100 or 250 ton-per-year thresholds would have applied.

As required by the CAA, all states, including California, are currently modifying their applicable air regulations and CAA State Implementation Plans (SIPs) to satisfy these new federal requirements. On September 2, 2010, EPA proposed a “SIP Call” that provisionally found that the applicable SIPs for thirteen states, including California (Sacramento Metropolitan AQMD), lacked adequate provisions to apply PSD requirements to GHG-emitting sources.

One issue to be addressed by EPA is whether CCS is deemed a best available control technology (BACT) in the future. BACT is applied on a case-by-case basis; takes into account energy, environmental, and economic impacts and other costs; and must be “achievable” for the facility.<sup>20</sup> EPA’s 1990 Draft New Source Review (NSR) Workshop Manual, which despite its draft status represents longstanding EPA policy and is used in BACT determinations to this day, states that “if the technology has been installed and operated successfully on the type of source under review, then it is demonstrated, and it is technically feasible.”<sup>21</sup>

From the source perspective, EPA has taken the following additional actions with respect to CCS. On October 30, 2009, EPA published its final rule requiring the mandatory reporting of GHGs (MRR).<sup>22</sup> The MRR applies to “Suppliers of Carbon Dioxide,” which includes, in part: (i) facilities with production process units that capture and supply CO<sub>2</sub> for commercial applications or that capture and maintain custody of a CO<sub>2</sub> stream in order to sequester or otherwise inject it underground; and (ii) facilities with CO<sub>2</sub> production wells that extract a CO<sub>2</sub> stream for the purpose of supplying CO<sub>2</sub> for commercial applications.

On December 1, 2010, EPA finalized a rule that included CCS in the mandatory reporting of emissions under the GHG Reporting Program.<sup>23</sup> A key feature of the rule is the use of monitoring, reporting, and verification plans covering CO<sub>2</sub> injection operations and geologic storage sites for emissions accounting purposes.

## **Pipelines**

There is no federal regulatory framework for siting CO<sub>2</sub> pipelines on private land, however, CO<sub>2</sub> pipelines can be sited on federal land under both the Federal Land Policy and Management Act and the Mineral Leasing Act. With respect to safety regulation, the U.S. Department of Transportation’s (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) has primary authority to regulate interstate CO<sub>2</sub> pipelines under the Hazardous Liquid Pipeline Act of 1979. CO<sub>2</sub> pipelines used to distribute CO<sub>2</sub> within an oil field for EOR are excluded from DOT’s regulation.

California does not have a statute specifically addressing the siting of CO<sub>2</sub> pipelines on state or private land. However, the CPUC could authorize the use of eminent domain by public utilities to site CO<sub>2</sub>

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<sup>18</sup> 75 Fed. Reg. 25324 (May 7, 2010).

<sup>19</sup> 75 Fed. Reg. 31514 (June 3, 2010).

<sup>20</sup> 42 U.S.C. § 7479(3).

<sup>21</sup> Draft NSR Workshop Manual, p. B.17 (EPA 1990).

<sup>22</sup> 74 Fed. Reg. 56260 (Oct. 30, 2009).

<sup>23</sup> 75 Fed. Reg. 75060 (December 01, 2010).

pipelines in conjunction with power generating facilities. With respect to safety regulation in California, the State Fire Marshal has “exclusive safety regulatory and enforcement authority over intrastate hazardous liquid pipelines” under the Elder California Pipeline Safety Act of 1981 and has adopted PHMSA’s safety regulations for this purpose. Lastly, it should be noted that literally thousands of miles of carbon dioxide pipelines are currently providing the gas for EOR operations in the Permian Basin in West Texas.

## **Geologic Injection and Storage**

### ***Hazard Classification of CO<sub>2</sub> Injectate Under Federal Law***

Perhaps of greatest relevance for geologic sequestration and for purposes of the pending Safe Drinking Water Act (SDWA) (42 U.S.C. §§ 300f to 300j-26) sequestration regulations (discussed separately below), EPA has referenced the CO<sub>2</sub> injectate with respect to the term “carbon dioxide stream,” which means: “carbon dioxide that has been captured from an emission source (e.g., a power plant), plus incidental associated substances derived from source materials and the capture process, and any substances added to the stream to enable or improve the injection process.”<sup>24</sup> According to EPA, carbon dioxide is not a hazardous substance under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) (42 U.S.C. §§ 9601 to 9675).<sup>25</sup> Thus, geologic sequestration of CO<sub>2</sub>, in and of itself, should not give rise to CERCLA liability. Sequestration of CO<sub>2</sub> could give rise to CERCLA liability, however, if the CO<sub>2</sub> stream contained constituents that are CERCLA hazardous substances from the source materials or the capture process or if the CO<sub>2</sub> stream reacted with groundwater to produce a CERCLA hazardous substance.

### ***Injection Well Regulation***

In November 2010, EPA announced federal requirements under the Underground Injection Control (UIC) program, as authorized by the Safe Drinking Water Act.<sup>26</sup> The final rule establishes new federal requirements for the underground injection of CO<sub>2</sub> for the purpose of long-term storage. A new well class—Class VI—has been listed to ensure the protection of underground sources of drinking water (USDW) from injection related activities.

The elements of the final rule include, but are not limited to:

1. Geologic site characterization to ensure the wells are properly sited
2. Requirements for the construction and operation of the wells that include construction with injectate-compatible materials and automatic shutoff systems
3. Periodic re-evaluation of the area around the injection well to incorporate monitoring and operational data and verify the movement of carbon dioxide according to prediction
4. Rigorous testing and monitoring of each project that includes testing of mechanical integrity of the well, groundwater monitoring, and tracking of the location of the injected carbon dioxide
5. Extended post-injection monitoring and site care to track the location of the injected carbon dioxide until it is demonstrated that USDW are no longer endangered
6. Clarified and expanded financial responsibility requirements to ensure that funds will be available for corrective actions, if necessary
7. Considerations for permitting wells that are transitioning from Class II (EOR) to Class VI that clarifies the primary purpose of the well.

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<sup>24</sup> 73 Fed. Reg. 43492, 43535 (July 25, 2008).

<sup>25</sup> 73 Fed. Reg. 43,492, 43,504 (July 25, 2008).

<sup>26</sup> [http://water.epa.gov/type/groundwater/uic/wells\\_sequestration.cfm](http://water.epa.gov/type/groundwater/uic/wells_sequestration.cfm)

These new requirements are designed to promote transparency and national consistency in permitting CCS activities while maintaining flexibility, as appropriate. It is unclear if the final regulations will allow States such as California to have primacy enforcement authority over the new Class VI wells. Section 1422 of the SDWA provides that the States may apply to EPA for primary enforcement responsibility to administer the UIC program; governments receiving such authority are referred to as “primacy States.”

### ***Long Term Stewardship***

Although there have been bills introduced on this subject in Congress, there is no federal program for the long-term stewardship of geologic storage sites during the site’s “post-closure phase,”<sup>27</sup> which is also sometimes referred to as the “stewardship period.”

### ***Financial Support***

The federal government has signaled its support of CCS technology development through a variety of funding assistance programs for qualifying CCS projects. A summary of these programs can be found in Appendix H.

### ***White House Task Force Report***

On August 12, 2010, the White House’s Interagency Task Force on CCS (Task Force) delivered its report to the President of the United States.<sup>28</sup> Co-chaired by EPA and DOE, the Task Force was charged with proposing a plan to overcome the barriers to the widespread, cost-effective deployment of CCS within ten years, with a goal of bringing five to ten commercial demonstration plants online by 2016. The report reflects input from fourteen federal agencies and departments, as well as hundreds of stakeholders and CCS experts.<sup>29</sup>

Appendix H contains additional information on federal activities pertaining to CCS regulation

## **2.6. Policy Developments in Other States**

Twenty states have enacted policies related to CCS. Policies in ten of those states are limited to studies and incentives, while the other ten states have addressed at least one of the major regulatory issues for CCS such as property rights, permitting rules, or long-term stewardship. Notably, none of the states with robust CCS policies have enacted state-level policies that limit GHG emissions like California.

A listing of CCS policies in other states is included in Appendix I.

## **3. Issues Requiring Attention and Resolution to Enable Safe and Effective CCS Demonstrations and Commercial Deployment in California**

### **3.1. The Regulatory Framework for CCS Projects**

#### **What Constitutes a Project?**

CCS projects will assume different configurations, however, there are several common elements between potential projects. Conceptually, CCS projects can be divided into CO<sub>2</sub> capture, transport, and storage components. The capture side, which includes the source of the CO<sub>2</sub> and the process whereby the CO<sub>2</sub> is separated and compressed, is likely to exhibit the greatest variety among projects. For example, the source

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<sup>27</sup> The U.S. Department of Energy, consistent with the laws of several states, considers the “post-closure phase” to mean the period after the site has been closed and “during which ongoing monitoring is used to demonstrate that the storage project is performing as expected until it is safe to discontinue further monitoring.”

[http://www.netl.doe.gov/technologies/carbon\\_seq/core\\_rd/mva.html](http://www.netl.doe.gov/technologies/carbon_seq/core_rd/mva.html).

<sup>28</sup> <http://www.epa.gov/climatechange/downloads/CCS-Task-Force-Report-2010.pdf>

<sup>29</sup> [http://fossil.energy.gov/programs/sequestration/ccs\\_task\\_force.html](http://fossil.energy.gov/programs/sequestration/ccs_task_force.html)



facility may be a power plant, refinery, cement plant, or ethanol plant, and the capture process may be accomplished with chemical or physical separation technologies.

The transport component of commercial-scale projects is unlikely to vary significantly among different projects, and will consist of dedicated networks of CO<sub>2</sub> pipelines. The sequestration aspect will likely exhibit some variability depending whether the storage formation is a depleted or actively producing hydrocarbon reservoir or a saline formation. However, in all cases, the storage infrastructure will consist of monitoring and injection wells, surface and subsurface monitoring equipment, and surface infrastructure related to the wells, monitoring, or management of CO<sub>2</sub> prior to injection and of any produced formation fluids. If CO<sub>2</sub> reuse technologies are involved in a project, facilities for manufacturing, for hydrocarbon separation, treatment, and transport, or for other types of processing may be co-located at or near the CO<sub>2</sub> source or pipeline.

### **Treatment of “Capture” Under Current California Law**

The permitting process for industrial development projects, such as CO<sub>2</sub> capture projects, in California involves a multitude of federal, state, regional, and local agencies, each with its unique authorities and regulatory requirements. Often, the agencies act independently of one another, and have permitting timeframes that are not closely coordinated. Typically, the first state agency to act on a permit application by a developer becomes the lead agency for the environmental document required under the California Environmental Quality Act (CEQA). The lead agency under CEQA coordinates its review of an Environmental Impact Report or Negative Declaration with the other responsible permitting agencies.

The current regulatory framework allows a project developer to approach different agencies at different times to initiate permit applications and to begin to address the environmental documentation requirements of CEQA. The timing of a permit application filing is the responsibility of the project developer.

### **One-Stop Permitting for Power Plants in California**

For the permitting of power plants, the Energy Commission serves as the lead permitting agency and also as the lead agency under CEQA. The Energy Commission’s 12-month, one-stop state permitting process is a certified regulatory program under CEQA.<sup>30</sup> The Energy Commission’s license and certification process subsumes the requirements of state, local, or regional agencies otherwise required before a new plant is constructed, while federal permits are issued within the timeframe of the Energy Commission’s licensing process. However, there have been cases where federal and state permitting timelines have not been closely matched. The Energy Commission coordinates its review of the facility with other permitting agencies to ensure consistency between their requirements and its own conditions of certification.<sup>31</sup>

To date, CCS has not been a significant factor in the Energy Commission’s siting process. In the case of a power plant project that involves carbon capture, the Energy Commission considers the environmental impacts of the entire facility and incorporates permit conditions to ensure that the CO<sub>2</sub> injection process is conducted in an environmentally safe manner. Under current law and regulations, these conditions of

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<sup>30</sup> Authority for power plant licensing by the Energy Commission is found in Public Resources Code Section 25000 et seq.

<sup>31</sup> PRC Section 25500 specifically provides: “In accordance with the provisions of this division, the Commission shall have the exclusive power to certify all sites and related facilities in the state, whether a new site and related facility or a change or addition to an existing facility. The issuance of a certificate by the commission shall be in lieu of any permit, certificate, or similar document required by any state, local, or regional agency, or federal agency to the extent permitted by federal law, for such use of the site and related facilities, and shall supersede any applicable statute, ordinance, or regulation of any state, local, or regional agency, or federal agency to the extent permitted by federal law.”

certification incorporate the regulatory requirements of other federal, state, regional, and local agencies into a single permitting process.<sup>32</sup> In most cases, applicable federal permits for activities associated with the power plants would still need to be obtained, since federal authority can pre-empt state authority.

Appendix O contains more information on permitting CCS projects in California.

### **GHG Issues Pertaining to the Regulation of CO<sub>2</sub> Capture**

Aside from the siting procedures described above, a set of climate related issues applies to the permitting of the CO<sub>2</sub> capture plants as well. These pertain to how California regulates GHG emissions in general, and CO<sub>2</sub> in particular. Specifically, the CPUC<sup>33</sup> (in the case of investor-owned utilities) and the Energy Commission<sup>34</sup> (in the case of public power) implement the Emissions Performance Standard (EPS), which was instituted under Senate Bill 1368.<sup>35</sup> The Energy Commission, counties, and other “lead agencies” consider whether CO<sub>2</sub> emissions constitute a significant impact and prescribe mitigation (CEQA or equivalent). ARB implements AB 32 by a cap-and-trade program and MRR, but California’s Air Districts can apply their own GHG standards to emission sources. For CCS projects the missing element is a protocol that recognizes CCS as a compliance mechanism under AB 32, and a protocol for quantifying the emission reductions.

CCS is already recognized as a compliance mechanism by the Energy Commission under the SB 1368 rules. In addition, CPUC modified its rules implementing the EPS in July 2009, to further clarify the content of the plan a load-serving entity must file as part of an application for a Commission finding that a power plant with CCS complies with the EPS.<sup>36</sup>

### **3.2. Regulation and Permitting of CO<sub>2</sub> Pipelines**

In many instances, CO<sub>2</sub> capture and CO<sub>2</sub> storage will not occur at the same site. Pipelines will be needed to transport captured CO<sub>2</sub> from the capture site to the injection site. This section briefly describes the current regulation of CO<sub>2</sub> pipelines in terms of both safety and siting authority. It also discusses tools to acquire or use rights-of-way for CO<sub>2</sub> pipeline.

Developing a transportation infrastructure to accommodate future CCS projects may encounter challenges regarding technology, cost, regulation, policy, rights-of-way, and public acceptance. However, given that CO<sub>2</sub> pipelines exist today and the similarity of this infrastructure to others that have been developed, such as natural gas pipelines, none of these challenges is expected to be a major barrier to deployment.

The need for CO<sub>2</sub> pipelines may not be limited to geologic storage projects, as pipelines would likely be needed to transport large quantities of CO<sub>2</sub> for any other process that may be developed for beneficially reusing, or otherwise handling CO<sub>2</sub> at commercial scales.

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<sup>32</sup> [http://www.energy.ca.gov/public\\_adviser/power\\_plant\\_siting\\_faq.html](http://www.energy.ca.gov/public_adviser/power_plant_siting_faq.html)

<sup>33</sup> [http://www.cpuc.ca.gov/PUC/energy/Climate+Change/070411\\_ghgeph.htm](http://www.cpuc.ca.gov/PUC/energy/Climate+Change/070411_ghgeph.htm)

<sup>34</sup> [http://www.energy.ca.gov/emission\\_standards/index.html](http://www.energy.ca.gov/emission_standards/index.html)

<sup>35</sup> Perata, Chapter 598, Statutes of 2006. The law ensures that long-term investments in baseload generation by the state’s utilities meet an emissions performance standard, set at 1,100lb CO<sub>2</sub>/MWh generated.

<sup>36</sup> Decision 10-07-046 of July 29, 2010 modified the existing rules (set forth in Decision 07-01-039) to clarify that the plan must comply with federal and/or state monitoring, verification and reporting requirements applicable to projects designed to permanently sequester carbon dioxide and prevent its release from the subsurface, and (2) to further specify how a plan may meet monitoring, verification and reporting requirements if federal and/or state requirements do not exist or have not been finalized. See:

[http://docs.cpuc.ca.gov/PUBLISHED/FINAL\\_DECISION/121474.htm](http://docs.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/121474.htm)

## **Safety**

CO<sub>2</sub> pipelines have been operating in the United States for almost 40 years, and there are approximately 3,600 miles of CO<sub>2</sub> pipelines in operation today. The Pipeline and Hazardous Materials Safety Administration (PHMSA), which is part of the Department of Transportation, regulates the safety of interstate CO<sub>2</sub> pipelines. Although CO<sub>2</sub> is not considered a hazardous liquid under PHMSA's regulations, it is effectively treated as if it were a hazardous liquid (i.e., subject to the same regulatory framework). These regulations address design, construction, operation and maintenance, corrosion control, and reporting requirements.

The CO<sub>2</sub> pipeline safety record, with respect to both the frequency and consequence of failure, is comparable to traditional gas transmission and hazardous liquids pipelines. There is very minimal risk associated with operating CO<sub>2</sub> pipelines. CO<sub>2</sub> is not flammable and the risk profile for CO<sub>2</sub> pipelines is somewhat different than for traditional gas transmission and hazardous liquids pipelines. However, special care must be given to a variety of design, operational, and human safety considerations in order to better compensate for CO<sub>2</sub> system-specific issues.

The State Fire Marshal has the "exclusive safety regulatory and enforcement authority over intrastate hazardous liquid pipelines" within California. The State Fire Marshal has adopted PHMSA's safety regulations. While there is some ambiguity (because carbon dioxide is not a hazardous liquid), it does appear that the State Fire Marshal could have the authority to implement these requirements and regulate the safety of any intrastate CO<sub>2</sub> pipelines in California.

## **Siting**

Because pipelines can cover large distances, siting pipelines can be extraordinarily complex. Construction in populated or environmentally sensitive areas poses significant challenges. It may be difficult for project sponsors to obtain rights-of-way, and the lack of eminent domain rights can necessitate the costly rerouting of pipelines, potentially leading to the cancellation of a project for economic reasons. Another natural consequence of lacking state condemnation authority is that rights-of-way may tend to target federal and state lands for crossing. The ability to get a land use agreement across government lands, both federal and state, will be a significant incentive and may result in less desirable locations being sought. Long CO<sub>2</sub> pipelines may prove to be impractical, if not impossible, to site without the power of eminent domain.

California does not have a statute specifically authorizing the use of eminent domain for CO<sub>2</sub> pipelines. In addition there is no federal authority for siting CO<sub>2</sub> pipelines on private land. Although public utilities in California can exercise the power of eminent domain in certain circumstances, other entities that could sequester CO<sub>2</sub> lack that ability, which could hinder the broader implementation of carbon sequestration. For that reason, legislation authorizing the use of eminent domain for CO<sub>2</sub> pipelines would likely further the implementation of carbon sequestration.

## **Rate regulation**

There is a particular need for flexibility in any law providing for the rate regulation for services provided by CO<sub>2</sub> pipelines, because of the current uncertainty as to who will own and operate such facilities, and what business model the providers of these services will use. The need for regulatory flexibility should be balanced with a need to provide potential industry participants with some degree of certainty concerning the applicable regulatory regime.

The approaches presented below illustrate the range of possible ways to regulate the rates, terms, and conditions of service of CO<sub>2</sub> pipelines and storage facilities.

- Approach 1 – CO<sub>2</sub> pipelines' rates and services would be left to commercial contracts.
- Approach 2 – An “open access/transparency” model of regulation would require CO<sub>2</sub> pipelines to provide open and non-discriminatory access both to owners of the facilities and to non-owners. This model would also emphasize public disclosure of commercial transactions and terms and conditions of service, but leave the negotiation of the specific rates, terms, and conditions of service to the mutual agreement of the commercial parties.
- Approach 3 – A traditional utility model of regulation would establish more detailed regulatory oversight of rates and terms and conditions of service along the lines of traditional public utility regulation. This approach would give a regulator the maximum amount of control over the rates, terms, and conditions of service.

### **3.3. Regulation of CO<sub>2</sub> Injection Under Current California Law**

CO<sub>2</sub> injection is governed under the Underground Injection Control (UIC) Program.<sup>37</sup> As described in a previous section, EPA has just issued regulations for a new class of wells for CCS (Class VI).<sup>38</sup> Class II governs CO<sub>2</sub> injection for the purposes of EOR. In California, EPA administers all well classes except Class II. The Division of Oil, Gas and Geothermal Resources (DOGGR) shares primacy with EPA for Class II wells. It is uncertain whether California will seek primacy for the Class VI well category, which governs CO<sub>2</sub> injection for storage.

### **3.4. Ownership of Pore Space for CO<sub>2</sub> Storage**

Geologic CCS projects are contingent upon the project operators obtaining the right to inject and store CO<sub>2</sub> within subsurface pore space. California courts have not addressed the issue of whether pore space is part of the surface or mineral estate, however, common law from other states indicates that pore space typically belongs to the surface owner.<sup>39</sup>

Under this scenario, implementation of a carbon storage project that underlies the properties of multiple owners could be stopped by a single owner's refusal to participate. This issue creates potential barriers for CCS projects in California. To better enable deployment of CCS, the state should consider addressing two issues related to pore space rights: 1) clarification of pore space ownership and 2) creation of mechanisms to acquire pore space rights.

The first issue—clarification of pore space ownership—could be addressed with a legislative declaration that pore space belongs to surface owners (at least by default). This would be consistent with legislation in other states (Montana, North Dakota, and Wyoming), and existing treatment of pore space in the context of oil and gas production and natural gas storage. Alternatively, the legislature could declare pore space to be a public resource or choose to recognize private interests in pore space only when the property owner has a reasonable and foreseeable use of it.

<sup>37</sup> <http://water.epa.gov/type/groundwater/uic/index.cfm>

<sup>38</sup> Ibid.

<sup>39</sup> Even though pore space in California is most likely part of the surface estate, the mineral estate has a dominant right to use the pore space in the production of valuable minerals. For this reason, oil and gas lessees typically have the right to inject and store CO<sub>2</sub> in pore space but only for so long as oil and gas production is occurring and only to the extent necessary for oil and gas production.

The second issue—mechanisms to acquire pore space rights—could be addressed by establishing authority for CCS projects to obtain these rights either by eminent domain or by unitization.<sup>40</sup> Eminent domain is commonly used to acquire property rights for projects that have a public purpose. Unitization is a long-established mechanism used in the context of oil and gas production, whereby hold-out property owners share in the revenues from production but cannot stop production from occurring. Louisiana has established a process by which to use eminent domain for carbon sequestration, and Montana, North Dakota, and Wyoming have authorized the use of unitization.

### **3.5. Requirements for Monitoring, Reporting, and Verification**

Monitoring, reporting, and verification (MRV)<sup>41</sup> can be undertaken for different reasons, including ensuring groundwater protection, quantifying and verifying GHG emission reductions, or validating model predictions. Thus MRV requirements can be quite varied depending on the purpose and any applicable statute requirements.

#### **Current State Laws or Regulations**

Numerous state regulations from ARB, the Energy Commission, CPUC, and DOGGR could incorporate MRV requirements. Statute requirements are discussed in Section II. None of the current regulations specify MRV requirements for CCS projects, although DOGGR does have requirements for MRV as it relates to protecting underground sources of drinking water during enhanced oil recovery operations. Since the current requirements only measure volumes and not specific content, these requirements would need to be revised for a CCS project in order to track how much CO<sub>2</sub> remains in the pore space. MRV requirements could be coordinated between the agencies with differences as necessary to meet statutory mandates.

#### **Relevant MRV Models**

MRV methodologies have been developed by different organizations for different purposes. EPA, the European Union, the Intergovernmental Panel on Climate Change, non-profits, industry organizations, and others are developing or have developed MRV plans for GHG accounting programs, injection safety programs, or for other purposes.

For example, under the Clean Air Act, EPA has expanded the MMR to include facilities that inject and store CO<sub>2</sub> for the purposes of geologic sequestration<sup>42</sup> or enhanced oil and gas recovery.<sup>43</sup> A key feature of this proposal is the use of “monitoring, reporting and verification” plans for geologic storage sites. In addition to MRV for GHG accounting purposes, EPA, under the Safe Drinking Water Act, issued a final rule for wells that inject CO<sub>2</sub> for sequestration.<sup>44</sup> This regulation has MRV requirements for the purpose of protecting underground sources of drinking water.

California could use these models as a starting point for its own regulatory efforts. Revisions may be necessary to ensure the MRV requirements are in line with California regulations, policy, and geologic conditions. Any revisions would likely need to include a public review process. In the case of MRV in accounting methodologies, ARB has harmonized its MRR with EPA reporting methodologies or incorporated third-party efforts for offset protocols, after a public review and revision process. For MRV for CO<sub>2</sub> injection, the state agency applying for primacy over Class VI wells (assuming California seeks

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<sup>40</sup> California could also consider how sequestration projects can obtain the right to use state-owned pore space.

<sup>41</sup> Other similar terms are frequently used including MVA for monitoring, verification, and accounting, and MMV for monitoring, measurement, and verification.

<sup>42</sup> 75 Fed. Reg 75060 (12/01/2010), see: <http://www.epa.gov/climatechange/emissions/subpart/rr.html>

<sup>43</sup> 75 Fed. Reg 75060 (12/01/2010), see: <http://www.epa.gov/climatechange/emissions/subpart/uu.html>

<sup>44</sup> <http://water.epa.gov/type/groundwater/uic/upload/GS-fact-sheet-111210.pdf>

primacy) must have authority as stringent as the EPA regulations. The MRV requirements of the different state agencies could be coordinated to ensure consistency and reduce administrative burden, as long as all the program goals and requirements are met.

### **3.6. Long-Term Stewardship and Liability of Storage Sites**

For CCS to be effective, the CO<sub>2</sub> must remain underground for a long period—hundreds or thousands of years. This requires institutional, administrative, and regulatory approaches for long-term stewardship to protect the public and to properly assess the efficacy of storage sites.

Although operational risks associated with the transport and injection of CO<sub>2</sub> in the subsurface during EOR operations have been successfully managed for many years, the long-term (post-closure) liability for CCS raises new issues. It is important to note that the entity accepting the liability will likely (without the development of institutional initiatives) be responsible for the cost of continuing MRV activities, any mitigation or remediation required, and compensation for any damages if leakage occurs.

After CO<sub>2</sub> injection ceases and well closure has been successfully completed, there is an extended period during which the behavior of the CO<sub>2</sub> in the subsurface will need to be monitored to track the size and location of the CO<sub>2</sub> plume, its movement, and ultimate stabilization. Such longer-term monitoring can provide a basis for determining whether the CO<sub>2</sub> remains contained and environmental credits may be claimed. The frequency of monitoring and whether it should be conducted by a public agency or a private entity is an additional factor to be resolved. There is no widespread consensus on how long the post-closure MRV phase should last, with opinions ranging from 10 to 50 years. The variation in these suggested timeframes arises from the fact that CCS technology is still new and there have not been enough large-scale demonstration projects to conclusively answer the question in all circumstances due to variables in location and the types of geologic storage formations involved.

Some confusion results from the observation that the terms “long-term liability” and “long-term stewardship” are often used interchangeably. However, these terms denote distinct concepts that should be kept separate. The term “stewardship” means primary responsibility for the ongoing operation, safety, and maintenance of the project, and especially the monitoring of CO<sub>2</sub> behavior in the reservoir. While this may appear to be less a legal than an operational issue, the determination of operational “ownership” will certainly carry a degree of liability. Long-term stewardship requires funding for administrative and operational oversight of post-closure MRV.

“Liability” is taken to denote financial responsibility for a CCS project, either in its individual phases or as a whole. This includes financial responsibility for what can be considered as normal industrial operations of a project, as well as financial responsibility arising out of an event or events that impact the health, safety, and/or well-being of people, including but not limited to impacts to the environment, drinking water, agricultural resources, and/or wildlife. Liability also includes financial exposure under a regulatory regime if CCS credits are used to meet carbon reduction goals and standards and the sequestration fails through leakage. Long-term liability, however, does not have a defined cost, but instead a risk factor that balances likelihood of an event against the monetary consequences of that event. This latter cost is currently rather difficult to establish for insuring long-term post-closure operations.

The issues raised by long-term liability are not amenable to one-size-fits-all resolution. In the absence of an affirmative government (federal, state, or local) policy decision to take on liability that it otherwise would not, liability issues are typically resolved either by resort to normal common law principles already in place or in special cases by negotiation on a case-by-case basis for particular contracts. In other words, it would be incumbent upon the operator to justify the need for public indemnity in a specific project. It may be ill-advised to invoke blanket public indemnity where, in individual cases, such may not be

required. Much discussion of liability has been in the context of limiting a company's exposure to long-term liability in order to promote the development of this technology in the "public interest."<sup>45</sup> However, creating innovative risk techniques, such as insurance, bonding, or pooled federal funding might encourage CCS development but also preserve federal and state liability frameworks to promote safe practices.

One option is for government agencies to take on the long-term responsibility for CCS sites after a certain number of years following the post-closure phase, by which time, the plume is largely or fully stabilized. The rationale for a government role in indemnifying long-term liability is due to the belief that CCS is in the public interest and that long-term liability issues should not, at this early stage in the development of the industry, be a barrier to further development. Some states have adopted legislation to accept varying limited liability. In some cases, the risk and performance of the CCS site is linked to liability transfer.

Another option is to create a carbon storage stewardship trust fund financed by fees from operators to ensure compensation for potential damages. Most of these programs respond retroactively, whereas CCS seeks a proactive framework. Where there is evidence of willful neglect of regulations or purposely providing misleading information, liability should be sought from the operator or descendants by the post-closure administrator. However, this is potentially difficult to determine, hence the desirability of a trust fund of some type.

Further discussion of long-term stewardship of CCS sites is found in Appendix Q.

### **3.7. Commercial Considerations/Incentives/Policy Drivers**

CCS offers the promise of large GHG emissions reductions via a relatively small number of projects at the state's largest industrial facilities, but it is a capital- and energy-intensive technology with long development leadtimes.

Although CCS involves component technologies that have been used commercially in various industries, CCS is not practiced in an integrated, commercial manner today at the scale necessary to make meaningful reductions in man-made GHG emissions. Yet, many GHG stabilization studies forecast CCS to be a major contributor to GHG emissions reduction, especially in the period after 2020. Thus, the focus of public and private sector researchers, technology providers, industries slated for GHG emissions regulation, and financiers/investors is to accelerate CCS commercial readiness and market introduction. Governments and regulatory bodies are encouraging technology development, demonstration, and early deployment through public policies and incentives.

Financial incentives to encourage investment in CCS demonstrations and early commercial projects tend to address one of three cost centers: capital cost, financing cost, and operating cost. Examples of federal incentives that reduce the capital cost of CCS projects are investment tax credits and U.S. Department of Energy cost share grants. An example of an incentive that reduces the cost of financing (and increases the likelihood of financial closure) is the U.S. Department of Energy loan guarantee program. Examples of incentives that reduce net operating costs are federal carbon sequestration tax credits (i.e., the Section

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<sup>45</sup> California has limited liability in various other situations when it is in the public interest. *See, e.g.,* CAL. CIV. CODE § 1714.5(b) (limiting liability for disaster service workers). However, courts have sometimes adopted "remedial innovations" when confronted with situations in which a serious loss occurred but no compensation was available. *In re Paris Air Crash*, 622 F.2d 1315, 1320 (9th Cir. 1980) (citing, among others, *Brown v. Merlo*, 8 Cal. 3d 855 (1973), in which the California Supreme Court held that a statute precluding automobile "guests" from suing the driver for negligence violated the equal protection clause).

45Q credits in the Energy Improvement and Extension Act of 2008) and accelerated equipment depreciation schedules.

State government incentives can also address these cost centers through programs similar to those offered by the federal government, such as investment tax credits and accelerated depreciation, and through credits or exemptions to taxes uniquely imposed at the state/county level, such as property taxes. California currently offers, for example, a property tax exemption for certain investments in renewable energy technologies, and it could consider a similar policy for CCS equipment.

Utility rate regulation is another area where states traditionally have jurisdiction. In many states, Public Utilities/Service Commissions have authority over cost recovery for power plants built or owned by investor-owned utilities, and for long-term power purchase contracts by investor-owned utilities from plants developed and operated by independent generators. PUCs can approve “above market” costs for power from generation sources deemed to be in the public interest, although such above market costs may adversely affect regulated utilities’ competitiveness in the retail electric market. In states where customers have access to energy service providers other than a local investor-owned utility, such as California, cost allocation mechanisms may be needed to socialize the above-market costs to all customers so that investor-owned utility customers alone do not bear the cost for the public-interest benefit.

The CPUC has authorized rate recovery for feasibility studies of integrated gasification combined cycle plants with CCS in exchange for public release of study results. Other states have a mixed record of support for such study costs, with some regulatory commissions approving, and some denying, rate recovery requests.

Where CO<sub>2</sub> emissions are regulated, annual allowances for emissions have been distributed to affected sources on the basis of historic emissions or benchmark values or via auction, or some combination thereof. In cases where allowances are auctioned, various proposals have been made to direct the resulting revenue to new technology demonstrations (including renewables and CCS), to energy bill assistance for low-income households, and to other related programs. Bonus allowances for early CCS adopters have also been proposed as a means to offset competitive challenges in the years immediately following application.

One rationale for California “topping off” federal CCS incentives is the recognition that costs for land, labor, materials, and utilities tend to be higher in California than the national average (by perhaps on the order of 20% on a blended average basis), and thus a higher total value of incentive would be needed here to engender the desired degree of market response.

Because CCS changes the production cost profile of power plants or other industrial manufacturing operations, they may be temporarily uncompetitive relative to plants without CCS, particularly in the era immediately after regulations take effect, when allowance price caps and other measures limit the price of CO<sub>2</sub> emission allowances. For power plants with CCS, for example, high dispatch rates are essential to minimizing levelized cost impacts on a per-kWh basis. The California Independent System Operator (dispatch center) has mechanisms to prevent dispatch curtailment for fossil power plants with CCS, typically designation as “must run” units. However, explicit affirmation on the placement of fossil power plants with CCS in California’s “preferred loading order” (which currently prioritizes energy efficiency and renewable s) may be desirable.

### **3.8. Role of Public Outreach, Education, and Acceptance**

Despite growing awareness of CCS in the energy, agriculture/forestry, environmental science, and policy communities, the general public remains largely uninformed about CCS technology and its potential role in mitigating adverse climate change. Given the magnitude of the challenge posed by global climate



change, it is in California's interest to have a knowledgeable populace prepared to engage in setting and implementing the state's climate and energy policies. The first step to meaningful public engagement on CCS is public understanding. It is natural for people unfamiliar with a technology to approach it with skepticism and concern, and it is the obligation of CCS policy and project stakeholders to invest in public outreach and education.

For policy-oriented agencies, CCS outreach will benefit by being positioned within the context of other major policy initiatives, principally energy supply and demand and the state's plan to reduce greenhouse gases to mitigate climate change. When CCS is presented in this manner, the public can better weigh its potential to contribute to the state's goal of fostering economic growth and opportunity while protecting human health and the environment.

It is often important to begin discussions of CCS by reminding people that CO<sub>2</sub> is a non-toxic, non-flammable, natural constituent of the atmosphere that plays an essential role in plant photosynthesis. However, this information needs to be presented along with some discussion of the increasing CO<sub>2</sub> concentrations in the atmosphere, which are leading to climate change. Although the risks associated with CCS projects are real and need to be addressed and explained, public perception of the risks is frequently based on unfamiliarity with subsurface storage mechanisms. Learning that storage takes place at depths more than half a mile deep and storage formations are overlain by sealing formations that prevent CO<sub>2</sub> from migrating upward can allay concerns about sudden catastrophic releases and water contamination.

Further discussion of public outreach by California agencies is found in Appendix L.

### **3.9. Environmental Justice**

The Environmental Justice (EJ) movement addresses the statistical reality that people who inhabit the most polluted environments are commonly people of color and the poor. Poorer communities, which often co-exist in proximity to facilities that have historically had negative environmental impacts, can be in line to host more of these types of facilities. Studies of these communities have shown that they exhibit higher levels of illness, disease, and premature deaths than do other areas.

Concerns of EJ communities often pertain to large industrial facilities such as power plants, refineries, cement plants, chemical plants, as well as truck and ship traffic, and issues associated with dumping and incineration sites. Fossil fuels figure significantly in EJ concerns because of impacts to air, land, and water associated with their extraction or production, the emissions from their refining and combustion, and their waste byproducts (e.g., coal ash and petroleum coke). EJ activists advocate moving away from the extraction and use of fossil fuels, and transitioning to sustainable alternatives.

EPA defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."

According to a presentation given before the Panel,<sup>46</sup> EJ advocates would expand EPA's definition to include "the avoidance of disproportionate environmental impacts on communities of low income residents and people of color, including:

- Cumulative health impacts on a region or community
- Fair and equitable use of government spending
- Health considerations sharing equal consideration with economic interests

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<sup>46</sup> [http://www.climatechange.ca.gov/carbon\\_capture\\_review\\_panel/meetings/2010-06-02/presentations/CCS\\_vs\\_Environmental\\_Justice\\_Document.pdf](http://www.climatechange.ca.gov/carbon_capture_review_panel/meetings/2010-06-02/presentations/CCS_vs_Environmental_Justice_Document.pdf)

- Long-term sustainability issues
- Fixing the health problems of dirty air and finding co-benefits of reductions in GHG emissions

In relation to CCS, a number of factors could lead to EJ concerns, depending on the location of a project. This is largely due to the fact that such projects will typically involve an industrial facility, although concerns over CO<sub>2</sub> pipelines and storage operations could also arise.

Materials on environmental justice are contained in Appendix M.

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## **4. Appendices**

### **Appendix A: Charter of the California Carbon Capture and Storage Review Panel**

#### **Purpose of the Panel**

The official title of the panel is “the California Carbon Capture and Storage Review Panel”. It has been created to advise the California Energy Commission, the California Public Utilities Commission, the Air Resources Board, the Dept of Conservation and other state agencies on CCS policy.

Panel members were chosen because of their strong interest and record of accomplishment in developing energy and environmental public policy. The goals of the Panel and its supporting advisory team will be to:

- Identify, discuss and frame specific policies addressing the role of CCS technology in meeting the State’s energy needs and greenhouse gas emissions reduction strategies for 2020 and 2050; and
- Support development of a legal/regulatory framework for permitting proposed CCS projects consistent with the State’s energy and environmental policy objectives.

#### **Tasks**

The Panelists will need to seek input from stakeholders and have the ability to direct and review informational material provided by a technical advisory team. The proposed meetings and subsequent deliberations will focus on:

1. Identifying and evaluating legal and regulatory barriers to deploying CCS
2. Consideration of CCS policy frameworks used elsewhere, gaps, alternatives, and their applicability in California
3. Developing specific committee recommendations

The product of this effort will be a final report from the Panel that discusses the major barriers identified, specific recommendations for resolving the regulatory and legal barriers, and the policy rationale for the recommendations.

#### **Technical Advisory Team**

The Panel will be assisted by a technical advisory team. This team will include consultants and State of California agency staff. Depending on the needs of the panel, the technical support team will be available to organize the meetings, collect information, conduct analyses, attend and write summaries of the panel meetings, and interact with California agency staff to develop briefing materials for panel members and assist in drafting the final report.

#### **Time Commitment**

Panel Members: Up to four meetings, travel to Sacramento for meetings, and approximately 2 days of prep time.

**Appendix B: Members of the California Carbon Capture and Storage Review Panel**

**Appendix C: California Carbon Capture and Storage Review Panel Meeting List of Presenters**

**Appendix D: Carbon Capture and Storage Technical Advisory Team**

**Appendix E: Uses of Carbon Dioxide**

**Appendix F: Geologic Suitability**

**Appendix G: Review of Saline Formation Storage Potential in California**

**Appendix H: Federal Overview**

**Appendix I: State-based Overview**

**Appendix J: Carbon Dioxide Pipelines**

**Appendix K: Approaches to Pore Space Rights**

**Appendix L: Public Outreach Considerations for CCS in California**

**Appendix M: Environmental Justice**

**Appendix N: AB 32 Regulations and CCS**

**Appendix O: Options for Permitting Carbon Capture and Sequestration Projects in California**

**Appendix P: Enhanced Oil Recovery as Carbon Dioxide Sequestration**

**Appendix Q: Long-Term Stewardship and Long-Term Liability in the Sequestration of CO<sub>2</sub>**

**Appendix R: Monitoring, Verification, and Reporting Overview**

**Appendix S: Overview of the Risks of Geologic CO<sub>2</sub> Storage**

**Appendix T: Establishing Eminent Domain Authority for Carbon Storage in California**